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Full Length Research Paper

Population size estimates and distribution of the African elephant using the dung surveys method in Rubondo Island National Park, Tanzania

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A study to estimate population size and distribution of elephants in the Rubondo Island National Park (RINP) was conducted between March and July 2014. It involved elephant dung survey methods. In estimating elephant dung pile density, a total of 217 dung piles were enumerated in 58 transects (each 1 km). The on-site dung decay rate computed from 100 marked fresh dung piles was estimated to be 0.01542 per day. By combining estimated dung pile density, on-site decay rate and defecation rate of 17 dung piles per day, the study found an estimate of about 102 elephants (95% CI, 72-144). Furthermore, results of this study indicate that, elephants were found to be more concentrated on the central and northern zones, which are the areas of the park that have some open glades allowing elephant to access the area easily to lake shores. The information generated from the study can be incorporated into setting up future management strategies for elephant conservation in RINP.

Key words: Rubondo Island National Park (RINP), distance sampling, dung pile density, decay rate.

INTRODUCTION

The African elephant *(Loxodonta africana)* is the largest terrestrial mammal and an icon of the African wilderness, the population of which is declining across its range (Blanc, 2008). The species is known to exist in a variety of habitats ranging from tropical forests, savannah to deserts and the species tends to extend habitats in searching for food, water and cover (Blanc, 2008 Stephenson, 2007). Some findings have shown that elephants need large home ranges and require extensive areas to meet their basic metabolic requirements

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(Shannon et al., 2008).

The elephant populations are declining in most protected areas across the region due to poaching and habitat loss (Blanc, 2008). In 2007, it was estimated that elephant numbers on the African continent were between 472,269 and 689,671 (Blanc et al., 2007). Currently, it is estimated that the African elephant population ranges between 419,000 and 650,000 individuals, and these are predominantly found in Southern and Eastern Africa (IUCN/AfESG, 2013). Blanc et al; (2007) estimated that 39% of the African elephant's range is found in Southern Africa, 29% in Central Africa, 26% in Eastern Africa and only 5% in West Africa (UNEP/CITES/IUCN/TRAFFIC, 2013). Population estimates of large herbivores can aid management decisions if estimates are accurate and precise. Therefore, survey intensities should be done in a way that could yield accurate and precise population estimates and detect population changes for several African elephant populations. Based on ground and aerial censuses the elephant population in Tanzania was estimated to be about 109,051 individuals (TAWIRI, 2009). In 2013, it was reported that, there were only about 13,084 (± 1,816 SE) elephants in the Selous - Mikumi ecosystem and these estimates are stated to be the lowest records since the time when census began in 1976 (TAWIRI, 2013). By 2014, there were about 43,521 (± 3,078 SE) elephants in Tanzania (TAWIRI, 2015). Hence, there is a decline by 60% from 109,051 (± 5,899 SE) elephants in 2009 (TAWIRI, 2015).

Since introduction of six immature elephants (two males and four females) between 1972 and 1973 (TANAPA, 2003), the park management has been lacking reliable updated information on population size of the elephants and their interaction with various habitats in RINP. It is impractical to use the direct count surveys in estimating abundance of elephants in forest areas. The dung count method was employed in estimating the population of the elephants in RINP, as it is recommended for areas where the observer(s) cannot openly and clearly see the animals in the study area (Barnes, 2001).

The dung count technique provides precise estimates that could be comparable to both direct counts and aerial surveys (Barnes, 2001, 2002). The combination of dung pile density, defecation and decay rate of dung piles is used for estimating population sizes of animals in forest areas (Barnes and Jensen, 1987). Dung count surveys provide good estimates with reasonable confidence limits (Barnes, 2002; Eggert et al., 2003). The minimum samples suggested for indirect surveys in the field ranges between 60 and 80 (Varma et al., 2012). For example, the dung count method was used to estimate the population size of 124 elephants (95% CI, 44-242) in Sapo National Park, Liberia with an estimated area of 630 km^2 (Yaw and Sani, 2009). Following RINP to have closed vegetation, may impose difficulty for aerial and ground surveys. The dung count method is suitable for providing information for long-term management of elephant population and habitats on the Island.

MATERIALS AND METHODS

Study area description

The study was carried out in RINP, in the south-western portion of Lake Victoria that lies 2° 18′ S and 31° 50′ E (Figure 1). Rubondo Island National Park was gazetted in 1977 and became the tenth National Park in Tanzania (TANAPA, 2003). The park covers a total area of 456.8 km^2, of which half (236.8 km^2) is dry land (TANAPA, 2003). The altitude of the park ranges from 1,100 to 1,500 m. It receives bimodal rainfall with long rains occurring from March to May, short rains from October and December and a dry season of January-February (TANAPA, 2003). Temperature is moderate ranging from 16 to 26°C (TANAPA, 2003).

Vegetation consists of mixed evergreen and semi-deciduous forest with common species including *Croton sylvaticus, Drypetes gerrardii* and *Lecaniodiscus fraxinifolius*. The island consists of a dense understory of lianas, or woody vines (Moscovice et al., 2007). Common native fauna include the vervet monkeys *(Cercopithecus aethiops),* sitatunga *(Tragelaphus spekei)* and bushbuck *(Tragelaphus scriptus).* Several mammals were introduced on the island including black rhino *(Biceros bircornis),* chimpanzees *(Pan troglodytes),* giraffes *(Giraffa camelopardalis)*, black and white colobus monkeys *(Colobus abyssinnicus)* and Suni antelopes *(Neotragus moschatus)* (TANAPA, 2003). Black rhino has become extinct on the island during the wave of poaching in East African countries including Tanzania in 1980s (TANAPA, 2003).

Study design and data collection

Elephant dung pile-decay rate

The decay rate study was designed based on the information of sites reported to have frequent elephant visits. In addition, some fresh dung piles that were encountered during survey of dung density were included in the dung decay study. Due to limitation of time and financial resources, the prospective method was employed. Through this method, fresh dung piles were marked and monitored at specific time intervals until their disappearance. Searches and monitoring of marked fresh dung piles took about three (3) months. Following the methods established by Alfred et al. (2010), elephant dung piles were classified as fresh meaning less or equal to 24 hours post-defecation based on the presence of flies, odour and moisture. Fresh dung piles were marked with wooden rods and tagged with pieces of printed tape of 1 m in length. Monitoring of decay rate was done after every five to seven days for a period of three months. The dung disappearance score was assessed during the monitoring time period based on the categories of classification as established by (Barnes, 2002; Alfred et al., 2010).

Other parameters pertinent to dung decay rate including presence of flies, dung beetles, vegetation type, canopy cover, altitude, local name of the site and weather were also noted. The location of dung piles was marked by GPS to aid monitoring and estimation of dung disappearance rate. Other tools used during data collection included, measuring tape, digital camera, field knife and folder file.

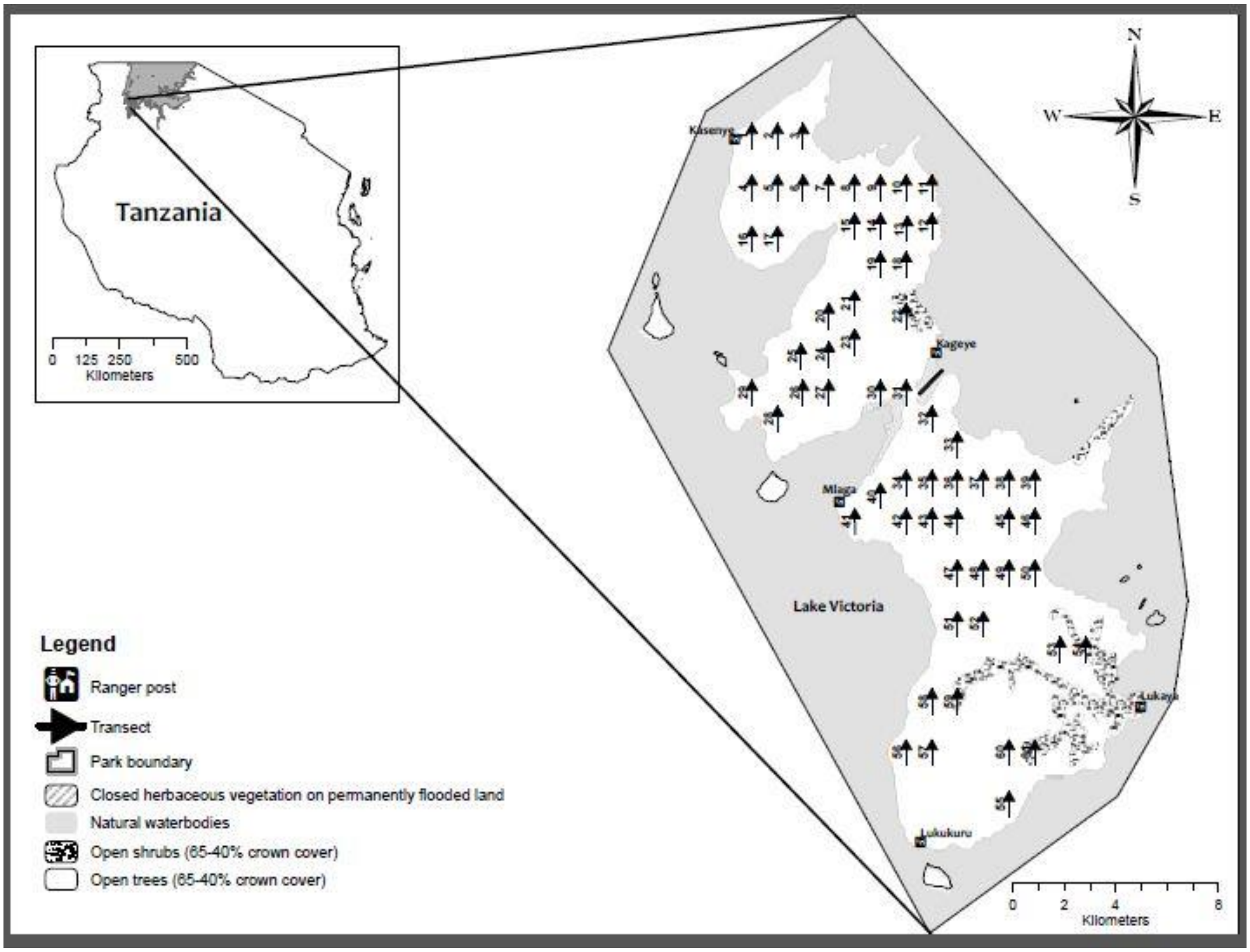

Figure 1. Map of Tanzania (inset) showing the study location of RINP.

Dung pile density

The standard line transect method was used in estimating elephant dung pile density (Buckland et al., 2001). Surveys for enumerating number of dung piles on the island along the designed line transects took three months. Prior to data collection line transects were systematically distributed on a map of RINP with a fixed length of 1 km and at intervals of 1 km apart (Figure 1). Transects were all designed to run in a south to north direction. Estimation of density of elephant dung piles was based on three major assumptions; dung piles within each transect could be detected with certainty, dung piles were detectable at their initial location and measurements of perpendicular distances were exact (Buckland et al., 2001). The tape measure was used to work out perpendicular distances from transects to the centre of the dung piles encountered.

Classification of dung piles for enumeration used in estimation of dung pile density was based on criteria (S1-S5) developed by Alfred et al. (2010). A total of 58 transects were used for dung survey in determining elephant density and distribution in RINP. To obtain comprehensive information on dung counts, surveys were conducted between 9 am and 4 pm every day to minimize the effect of canopy cover on detecting dung piles along the line transects. A team consisting of three personnel (one researcher, one field assistant and one armed park ranger) walked along transects.

Distribution of elephants in RINP

Elephant dung piles encountered through transect surveys were recorded as indicators of distribution. Other indicators of distribution such as elephant trails, wallowing sites, live elephants, foraging signs, carcasses and foot prints were also noted.

Data analysis

Elephant decay rate and dung piles density

The statistical programme GENSTAT was used in calculation of the mean survival time of dung piles (Meredith, 2007). Elephant dung pile decay rate was obtained by finding the mean survival time of all decayed samples and then the reciprocal value obtained was considered to be the estimate value for decay rate per day in the area (Buckland et al., 2001).

Computation of dung pile density was performed by using the DISTANCE 6.0 program (Thomas et al., 2010). Five models were

Table 1. Summary of results of elephant dung pile density by using five models on DISTANCE® program.

Model used	#Parameter	AIC	ESW/EDR	D	%CV	95%CI	
						Lower	Upper
Half normal+cosine	2	704.4	3.59	520.7	20.06	351.21	772
Half normal+simple polynomial	2	713	3.65	512.8	18.12	358.45	733.5
Uniform+cosine	2	718	3.48	537.6	17.12	382.71	755.3
Hazard rate+cosine	2	691.8	3.95	473.2	17.35	335.43	667.6
Hazard rate+Hermite polynomial	2	691.8	3.95	473.2	17.35	335.43	667.6

Explain this (AIC, ESW/EDR, D, %CV, 95%CI)

fitted to obtain precise estimate of the elephant population as recommended in distance sampling (Table 1). There was no difference on the outputs when truncation applied to various models. The hazard rate model with some adjustments (Cosine and Hermite) gave consistent results with lowest Akaike's Criterion Information (AIC) values. Hence, by having lower AIC value and sound histogram, these models were considered as the best estimators for density of elephant dung piles.

Elephant density and numbers

The dung pile density obtained by the distance programme (Buckland et al., 2001) was converted to elephant density. Due to limitation of time and financial resources, adopted defecation rate of 17 dung piles per day for Kibale National Park in Uganda was used in estimating the population size of elephants (Wing and Buss, 1970). Calculation of density and number of elephants was done according to McClanahan (1986), Barnes and Jensen (1987).

$$E = \frac{DR}{Y}$$

Where, E represents elephant density, D is the dung pile density obtained from distance analysis (Buckland et al., 2001), R is the dung decay rate and Y represents the defecation rate.

The combination of estimates of dung pile density, decay and defecation rates was used to give an estimate of population size of elephants in Rubondo Island National Park. The distribution of indicators of elephants was analysed by assessing the percentage of encounters of indicators in different habitats on the island.

RESULTS

Dung decay rate, dung piles density and elephant population estimates

Five sites encountered with fresh dung piles were surveyed; Maji Matakatifu (4 dung piles- woodland), headquarters (23 dung piles-woodland), air strip (21 dung piles-open woodland), road to Mlaga ranger post (30 dung piles-woodland) and Mlaga campsite (25 dung piles - glade), Kamea road (1 dung piles - woodland) and Mlaga to Lukaya/Lukukuru road (11 dung piles - woodland). Although 115 fresh dung piles were marked and monitored in various habitats, 100 dung piles were used for the determination of decay rate as 15 were not relocated. This was due to the disturbance led by road maintenance of road from headquarters (Kageye) to Mlaga ranger post.

Mean survival time for dung piles was 64.842 (S.E. ± 1.36) days with coefficient of variation of 2.097. The elephant dung pile decay rate was 0.01542 per day. A total of 217 dung piles were enumerated in a total length of 58 km of parallel line transects. The elephant dung piles density was estimated to be 473.22 (95% C.I. 335.43- 667.60) dung piles per km^2 (Table 1). Akaike's Information Criterion (AIC) provides a quantitative method for model selection and model with lowest AIC is selected for final analysis and inferences (Buckland et al., 1993). It attempts to identify how the model that fits with the data well. Based on the findings of this study in determining the dung piles density, Hazard rate with cosine and hermite polynomial adjustments gave the lowest AIC values (691.8) (Table 1). Effective strip width (ESW) is the average distance where dung piles were detected during dung count survey. The coefficient of variation (CV) gives a measure of precision of the estimate and is usually expressed in percentage. Outputs having low variances are considered to be more precise. The model which was considered to give the precise estimate has a percentage of coefficient of variation of 17.35 (Table 1). The 95% confidence interval (CI) is used in determining the lower and upper value of an estimate. In DISTANCE program AIC, ESW, %CV and 95%CI are computed automatically.

Basing on the findings of this study, RINP was estimated to have about 102 elephants (95% CI, 72-144). The density of elephants in the RINP was estimated to be less than one elephant (0.43) per km^2.

Distribution of elephants on the Island

About 523 of elephant signs were recorded during the survey. Dung piles including other indicators such as elephant trails, carcasses, live elephants, wallowing sites, foot prints and foraging signs were also observed. It was

Table 2. Summary of percentage of encounter (s) of indicators of elephant distribution in RINP.

Indicators of elephant distribution	Number of encounter(s) of indicator	Percentage
Dung piles	343	65.58
Trails	50	9.56
Foot prints	56	10.71
Wallowing sites	18	3.44
Foraging signs	46	8.80
Live animals	8	1.53
Carcasses	2	0.38

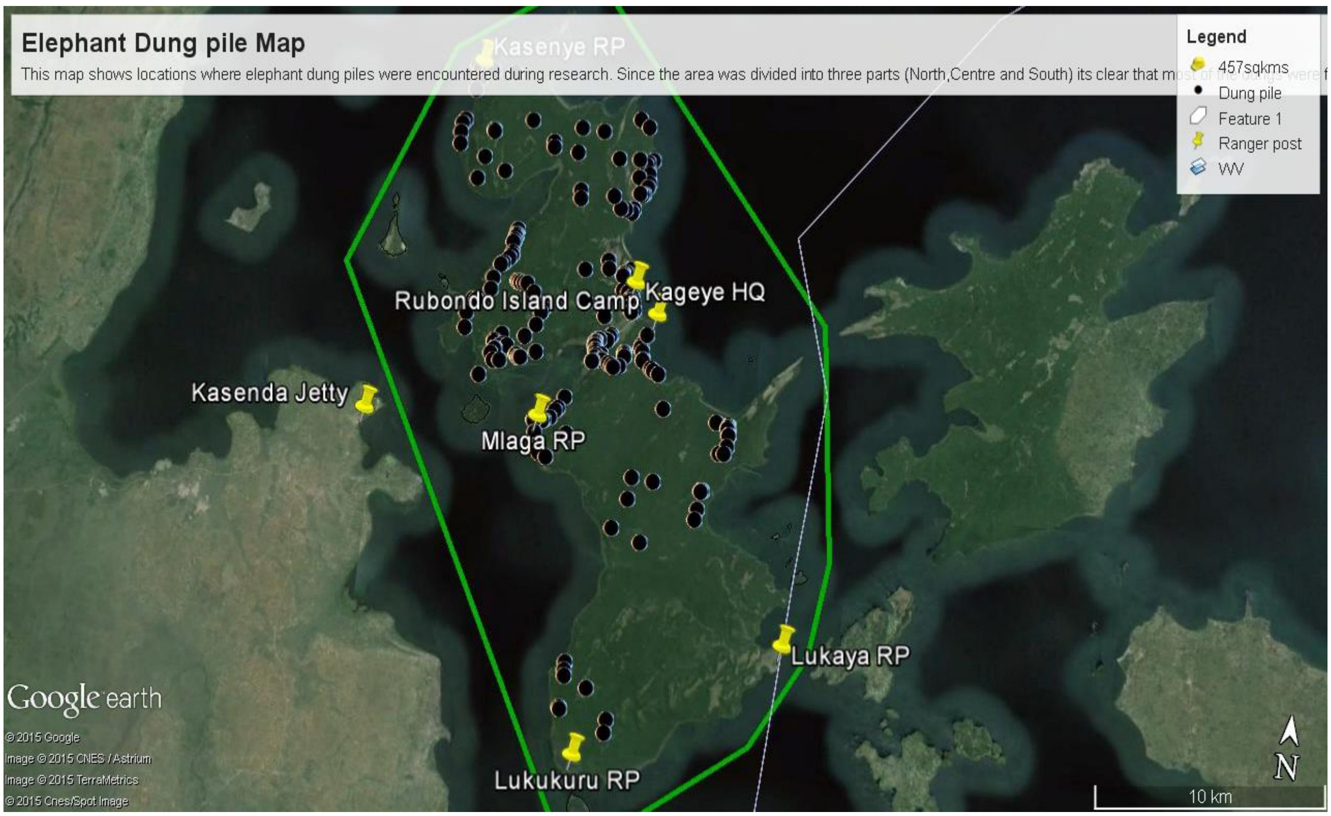

Figure 2. Map of RINP showing distribution of dung piles as indicators of presence of elephants in various habitats.

found that 65.58% (N=343) of dung piles and 0.38% (N=2) of carcasses as the highest and lowest encounters, respectively (Table 2). Two carcasses of elephants were found in the central and southern zones of the park with tusks intact. Elephant activities were mostly observed to be concentred on the central and northern zones of the study areas (Figure 2). Frequent visits of elephants have been reported to ranger posts associated with feeding activities. Most encountered plant species browsed by elephants included *Annona senegalensis, Phoenix reclinata, Ekerbegia capensis* and *Aeschynomene elaphroxylon.*

DISCUSSION

Elephant dung pile decay rate

The study of elephant dung pile decay rate as a means of estimating abundance of elephants was the first to be conducted in RINP. A precise estimate of decay rate in the study area was considered to yield precise estimates of elephant numbers in forest areas. Dung piles, deposited in areas with high vegetation canopy cover were observed to decay faster compared to those underlow or no canopy cover. This may be due to the steady environmental temperatures which favour a higher rate of dung decomposition. Deposition of dung piles in habitats without canopy cover exposes microorganisms (dung beetles, termites and microbes) to unfavourable conditions for decomposition to take place. The climate variables (rainfall, irradiance and temperature) and elephant diet are also considered as the determinant of elephant dung piles decay rate (Barnes, 2001). Moreover, the nature of food materials of plant species eaten by elephants has great influence on disappearance of deposited dung piles.

Elephant density and population estimate

Results from this study show that, there has been an increase in the number of elephants from six (6) in 1973 to 102 elephants in 2014, implying that the RINP elephant population is increasing. Forage biomass, forage quality, water availability, shade and plant species composition has correlation with density and distribution of elephants (Harris et al., 2008). Increase in elephant population in RINP may be contributed by receipt of enough rainfall annually, presence of water body surrounding the island, high canopy covers. Availability of shades almost over the island makes RINP as the suitable habitat for elephants in regulating metabolism of these large herbivores.

These findings are indicative of the fact that, elephant population growth on Rubondo Island is promising. Based on the physiognomy, paved paths and resources utilized by elephants on the island, findings of this study suggest that the island is able to support the existence of wildlife species. However, due to limited size of the island with only dry land of 236.8 km^2, large number of elephants may exceed the carrying capacity of the area probably in the future. As a result, the ecosystem on the island may lose its aesthetic value due to overexploitation of resources by elephants. Until the time of the survey, only three elephant carcasses with tusks had been reported in all three incidents, it is possible that the deaths were caused by natural factors. There has been no field report of elephant poaching on Rubondo Island. The detection probability during transect survey in enumerating number of dung piles was affected by a number of factors, including composition of understory since the nature of vegetation in RINP is vast rain forest type. Cloudy weather and canopy cover also influenced poor performance of GPS and the ability to detect dung piles during transects surveys. Traditionally, steep terrain and dense woods pose some hindrances in accessing some areas, which was also the case during the current survey in the southern part of the park.

Distribution

High density of dung piles was found at the central and northern parts of the park indicating presence of more elephants in these areas (Figure 2). Some studies have shown that, resources availability and accessibility influence the elephant activities (Shannon et al., 2008). Raphia swamps were found to have high level of elephant activities in Sapo National Park in Liberia (Yaw and Sani, 2009). In fact, suitable habitats are preferred by elephants. Presence of good road network and tracks at the central and northern zones enhance easy movement of humans and animals near or along the tracks. Occurrence of elephants in small herds encourages flexible movement between different habitats. High density of dung piles was also encountered close to the lake shore, revealing that availability of water predicts movement and activities of elephants in RINP. During periods of shedding leaves by trees, elephants were observed to prefer utilizing habitats along the lake. In some circumstances elephants were observed browsing on *Aeschynomene elaphroxylon,* which is found in water near the lake shore. In some other instances, elephant signs were encountered in habitats where lemon trees are found. Remains of lemon fruit were observed among contents of some elephant dung piles. *Phoenix reclinata* is mostly utilized by elephants because it can easily be uprooted and eaten. Foot prints, trails, carcasses, wallowing sites and elephants themselves were regarded as other signs indicative of presence of the mega herbivores and their related activities in various habitats.

Conclusion

Findings of this study have shown that, the elephant population in RINP is increasing. This remark may be due to low level of poaching and successful adaptation of elephants to environments in forest areas on the island. High concentration of dung piles at the central and northern zones of the park may imply the availability of suitable habitats for elephants. It is recommended that, park management should continue to monitor population trend of the elephant on the island in specific interval of time. Moreover, further studies are needed to determine the carrying capacity of the island. This may be helpful in controlling the number of elephants so that cannot disrupt the welfare of other wildlife species on the island. In context of contemporary management of endangered wildlife species, in future there is a need to undertake genetic studies to undertake the inbreeding risks of isolated small population on the island.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Assessment of diversity and conservation status of plants at Mount Kenya University Medicinal Botanical Garden, Thika sub-County, Kiambu County, Kenya

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The studies on biodiversity of living organisms as well as the ecosystems which they are part of is essential for the assessment of species composition and setting priorities in conservation matters. The plant diversity assessment at Mount Kenya University Medicinal Botanical Garden was done over a period of three years using both individual observation and line intercept/point centered quadrant methods on five designated zones of the garden. A total of 248 plant species of 60 families were recorded. Most of the plants that were found in this garden were indigenous (90%) and in use categories the occurring class was the medicinal (44%). Poaceae constituted the highest composition of 31 species (12.5%), followed by Asteraceae with 20 species (8%) and Euphorbiaceae with 15 species (6%). The rocky and exotic vegetation had high plant family diversity and the riverine had the least. It was concluded that the botanical garden was improving in its species composition and continued conservation and sustainable use will be important for the education and research services.

Key words: Mount Kenya University, Shannon's indices, Simpson's index, point centered quadrant.

INTRODUCTION

Biodiversity refers to the variety of life on earth, including plants, animals, and microorganisms, as well as the ecosystems which they are part of. It also includes the genetic differences within and between various species (Secretariat of the CBD, 2005). Globally, there are about 13 million species, but only about 1.75 million have been

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identified and the estimates show that 90% are animals, 80% plants, and 10% microorganisms (Otswongo, 2009). Biodiversity provides about 40% of the global market goods and services (Lusweti, 2011). World population exploitation in the recent past has posed great threats on biodiversity due to overuse, loss of habitat, and environmental pollution. The Millennium Development Goals number seven and the convention of biodiversity emphasize on the need for environmental sustainability and conservation for meeting life demands on earth (Secretariat of the CBD, 2005).

Medicinal plants form the backbone of traditional medicine practices that have existed since antiquity and have evolved through a number of civilizations. There are between 200,000 and 250,000 higher plants on earth and at least 35,000 species have been documented to be of medicinal use across various human cultures around the world (Bodeker et al., 1997; William, 2009). In Africa, there are between 50,000 and 70,000 plant species which besides being used in crude form have also been of great contribution to the development of drugs used in conventional medicine practices. Examples include morphine (*Papaver somniferum*), vincristine and vinblastine (*Catharanthus roseus*) and emetine (*Cephaelis ipecacuanah*) (Nigro et al., 2004). This implies that conservation of medicinal plants is essential for continued research of human and veterinary medicines as well as for other economic purposes.

Kenya is a country that lies within the tropical regions known to be rich in biodiversity (Lusweti, 2011). The country covers an area of about 582,900 km^2 with over 35,000 of flora and fauna. Plant population is between 8000 and 9000 and about 2000 are shrubs and trees, while about 24,000 are animals and the rest are microorganisms (Mugabe et al., 1998). There are about 1,200 medicinal plants that have been identified for use in Kenya and 70% of Kenyan human population which is over 40 million, rely on traditional medicines for their primary health care needs (Odera, 1997).

Additionally, more than 90% of the population uses these medicinal plants at one time or another to prevent, cure or manage various health conditions. Like other spheres in the universe, the Kenyan population may pose threats to biodiversity and therefore affect the livelihoods of people, influence their lifestyle as well as climate change which may translate to fatal consequences. As a result, the Kenyan government has put measures that would lead to conservation of biodiversity by being a signatory to CBD. The constitution of Kenya, chapter five emphasizes on the need for environmental conservation and sustainability as a national commitment (National Council for Law, 2010) and too biodiversity is envisaged in the three pillars of economic, social, and cultural diversity in the effort of achieving vision 2030 for the country (Kenya Vision, 2030, 2007).

The purpose of this study was to identify the plant diversity at Mount Kenya University botanical garden, categorize the plants and determine the abundance of various plant families growing there.

MATERIALS AND METHODS

Study area

This study was carried out at Mount Kenya University Botanical Garden located along Garissa Road, about 7 km from Thika town, Kiambu county, Kenya. It abuts Chania River to the North, the University Graduation pavilion to the south and Riverside estate to the east (Figure 1). The garden covers about 78,000 m^2 (19.27 acres) of land and is characterised by vegetation of both open Woodland and Grassland. The site is defined by the following GPS cordinates: 1°3'2"S, 37°8'9" E, 1°3'4"S, 37°8'22"E, 1°3'8"S, 37°8'6"E and 1°3'9"S, 37°8'24"E.

The site's altitude ranges from 4700 to 4,788 ft above the sea level with a gradual slope from the Northern to the Southern side. Although the vegetation zone in Kiambu county is largely characterised by highland climate. The outskirts of Thika sub-county, where the site is situated are notably a gradual transition into the grassland vegetation zone towards the South East of the country.

Plant species documentation and diversity assessment methods

General vegetation sampling methods

The botanical garden was subdivided into five designated sites consisting of rocky vegetation, soil dumping vegetation, heavily cultivated site, exotic plantation, and riverine vegetation. A general botanical inventory was carried out in 2012 during the dry season (January- March) and subsequent documentations were done during the wet season (August-September) with the aim of enriching the final species checklist. The data obtained was ecologically analyzed as per the subdivisions as indicated in Table 1.

Line intercept and point centered quadrant method

Data was collected by random sampling using transect-quadrat method in all the three subdivided regions (rocky vegetation, soil dumping area and riparian vegetation). For a systematic study of vegetation, seven line transects were demarcated. They were all diverging from one geo-referenced point (S01˚ 03’ 07.3“, E037˚ 08‘20.1”) and run in different directions with the edges of the study site as the radii. Along each line transect, quadrants were demarcated each measuring 50 m × 50 m with an interval of 10 m. A total of 28 quadrants were demarcated as shown in Figure 2. Observations of the plant species that were found at every quadrat were counted and recorded at individual level (Erenso et al., 2014; Rao et al., 2014). A summary table and sketch map of the study area showing respective transects and quadrants in various habitats are shown in Table 1 and Figure 2, respectively.

Data analysis

The data obtained was analyzed using both qualitative and quantitative statistical tools to reveal various measures of biodiversity including species richness, relative abundance, and species evenness. Shannon’s indices (H and J values) and Simpson’s indices (D values) were used for demonstrating species diversity and evenness. Formulae used were as:

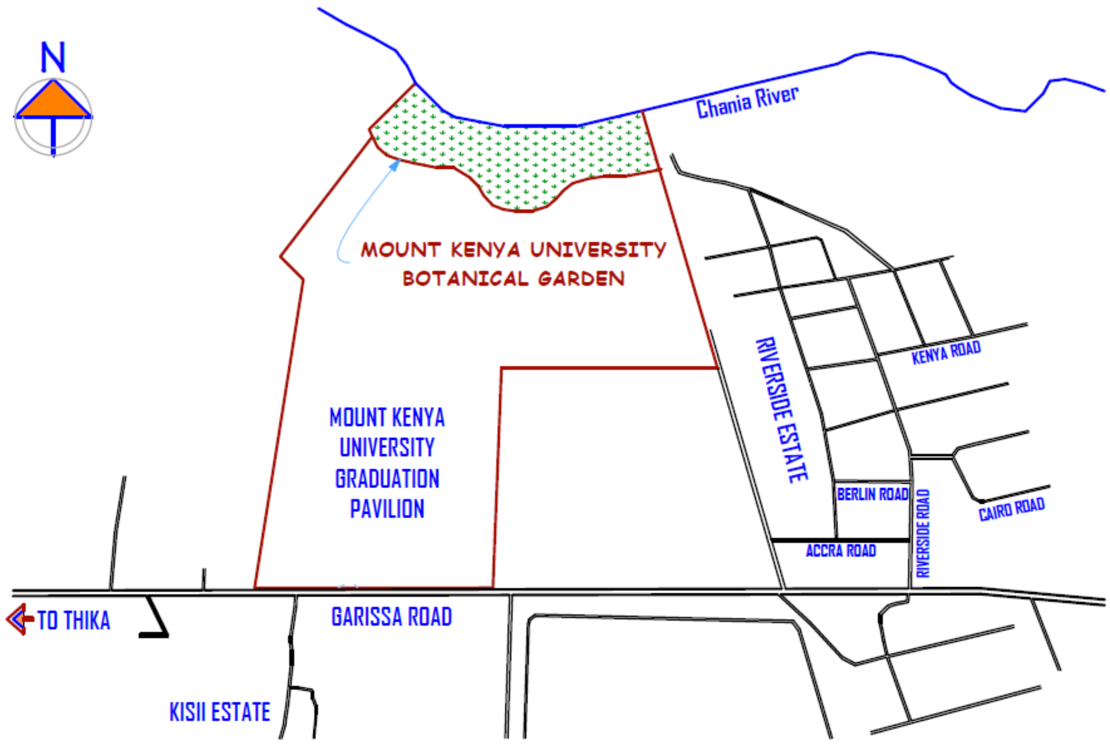

Figure 1. A sketch map showing the Mount Kenya University botanical garden.

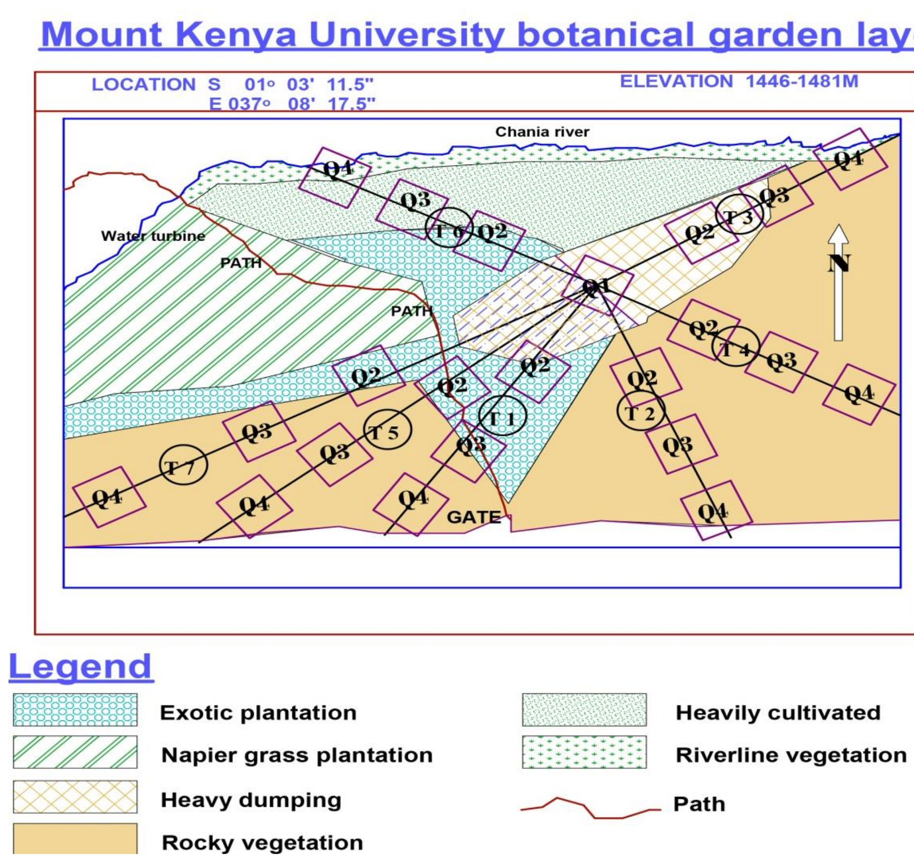

Figure 2. A sketch map showing the seven transects and corresponding quadrants.

Table 1. Location of transacts and quadrants in respect to various habitats.

Habitat	Area (m^2)	Transact and quadrant
Riverine vegetation	4,900	T3Q4 and TQ4
Heavily cultivated site	10,800	T6Q3
Rocky vegetation	42,000	T1Q2-4, T2Q2-4, T5Q3-5 and T7Q3-4
Heavy dumping site	6,600	T1Q1, T2Q1, T3Q1,T4Q1,T5Q1,T6Q1,T7Q1 and T3Q2
Exotic plantation	13,700	T2Q1, T5Q2, T6Q2 and T7Q2

D value $= \frac{\sum ni(ni-1)}{N(N-1)}$

where n= total number of families, N=total number of organisms at a particular habitat.

H value $=\sum_{i=1}^{f} -(pi \; X \; ln \; pi)$;

where f = number of families encountered, p_i=fraction of entire habitat made of family i, ∑= sum of families; in this case, 60.

(J) $= \frac{H}{ln(f)}$;

where H=Shannon's diversity index, f = number of families encountered.

RESULTS AND DISCUSSION

Description of study vegetation

A total of 248 plant species from 60 families were recorded, 90% of which were indigenous and 10% exotic. Classification of the plants on the basis of use revealed that a majority of the plants in the garden are medicinal (44%), while other use categories were classified as weeds (29%), wood (9.7%), food (4.1%), life fence (3.4%), fibres (2.6%), ornamental (1.5%), perfumery, fodder, biogas (0.4%) and other unclassified uses (4.5%). The other plant uses like oils, fertilizers, dyes, and poisons were not represented in this study. The plants that were identified constitute 27 species of trees (11%), 77 species of shrubs (31%), 98 species of herbs (40%), 29 grasses (12%), 9 climbers (4%) and 5 lianas (2%). The vegetation of the study area was threatened with environmental degradation from removal of woodland resources, such as firewood, medicinal plants, and building material, as well as agricultural encroachment, damping, and overgrazing. In fact vegetation once described as woodland no longer exists in this ecological zone. The vegetation has been reduced to open woodland and grassland with a big area planted with Napier grass and exotic tree species. The common open woodland species include *Dombeya garckeana*, *Ozoroa insignis*, *Euclea divinorum* and *Pappea capensis*. The *Acacia polyacantha*, *Combretum molle*, *Croton macrostachyus* grassland are characterized by tall grass of *Hyperrhenia filipendula*, *Themeda triadra*, *Aristida* species, *Digitaria* species, *Eragrostis* species and *Echinochloa haploclada*. The herbaceous layer is characterized by exotic weed of *Parthenium hysterophorus* and *Xanthium pungens*. Other common species includes *Aspilia mossambicencies*, *Ajuga remota*, *Bidens pilosa*, *Tagetes minuta* and *Phyllanthus* species.

The riverine vegetation has been reduced to a mere strip of less than 50 m planted with Napier grass (*Pennisetum purpueum*) being the dominant species. The findings of this study records more than 50% of the tree species and woodland plants that were found in a study carried out in Thika (Malobe and Mutangah, 2005). It is important to note that some of the highly valued medicinal plants, namely, *Aloe secundiflora*, *Zanthoxylum chalybeum*, *Prunus africana*, *Warbugia ugandensis, Maytenus senegalensis, Carissa spinarum, Withania somnifera, Kigelia africana Pavetta teitana,* and *Rhamnus staddo* are found in this study area. Though, *Combretum tanaense* and *Ficus scassellatii* ssp thikaensis were recorded for the first time in this area.

Family distribution in the botanical garden

Poaceae constituted the highest composition of 31 species (12.5%), followed by Asteraceae with 20 species (8%), Euphorbiaceae with 15 species (6%) and the others as shown in Table 2.

The calculations of abundance of the families in the designated habitats of the garden using Simpson' diversity index (D) revealed that the rocky area and exotic plantation site (D= 0.097) have more diverse families followed by the heavily cultivated area (D=0.011), heavy dumping site (D=0.13) and finally riverine with least diverse families (D=0.17). Further estimations of family abundance using Shannon diversity index (H) and evenness (J) confirmed that the rocky area was characterized by great family variations with equal abundance (H=3.93 and J= 0.96). Therefore, it can be said that there is a high chance of picking plant specimens belonging to the same family at the rocky area than at the riverine site (H=2.24 and J=0.55). Table 3

Table 2. Showing the percentage distribution of various families.

Percentage species composition	Number of families	Family name(s)
0.1-2	46	Agavaceae, Aloaceae, Amaranthaceae, Apocynaceae, Araliaceae, Asclepiadaceae, Bignoniaceae, Boraginaceae, Burseraceae, Cactaceae, Canellaceae, Capparaceae, Casuarinaceae, Chenopodiaceae, Combretaceae, Commelinaceae, Brassicaceae, Cucurbitaceae, Cupressaceae, Cyperaceae, Ebenaceae, Flacourtiaceae, Lythraceae, Malvaceae, Meliaceae, Moringaceae, Musaceae, Myrtaceae, Ochnaceae, Oleaceae, Papaveraceae, Passifloraceae, Phytolaceae, Pittosporaceae, Polygonaceae, Proteaceae, Rhamnaceae, Rosaceae, Santalaceae, Sapindaceae, Sterculaceae, Thymelaeaceae, Tiliaceae, Ulmaceae, Verbenaceae and Vitaceae.
2.1-4	12	Acanthaceae, Anacardiaceae, Caesalpiniaceae, Celastraceae, Lamiaceae, Malvaceae, Mimosaceae, Moraceae, Papilionaceae, Rubiaceae, Rutaceae and Solanaceae
4.1-6	1	Euphorbiaceae
6.1-8	1	Asteraceae
12.1-14	1	Poaceae

Table 3. Calculated D, H and J values.

Plant habitat	Simpson's index (D)	Shannon's diversity index (H)	Shannon's evenness index (J)
Riverine vegetation	0.1653	2.2364	0.5462
Heavily cultivated area	0.1166	2.4878	0.6075
Rocky vegetation	0.09695	3.9311	0.9601
Heavy dumping site	0.1346	2.6429	0.6455
Exotic vegetation	0.0973	2.7825	0.6796

shows D, H, and J values of the habitats of the botanical garden as calculated using the Simpson, Shannon's Diversity, and Shannon's Evenness indices, respectively

CONCLUSION AND RECOMMENDATIONS

The entire region of the botanical garden that was studied had no recognizable vegetation cover at inception and after now is covered with a great percentage of grass followed by woody vegetation and therefore can be designated as grassland and open woodland vegetation. Continued efforts of protection and conservation may result to further transition of vegetation cover and change in species (flora and fauna) composition. The intention of having to reclaim this part of land and making it useful to the society is highly promising. The fact that the medicinal plant composition is higher than any other categories of uses reflects it well as an exhibition for life specimens in learning and research situations. The researchers recommend that it is important for the university and other interested organizations to continue considering enriching and protecting the area as all works well for the whole country.

Conflict of Interests

The authors have not declared any conflict of interests.

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Review of policies, legislations and institutions for biodiversity information in sub - Saharan Africa

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Over the past three decades, most sub-Saharan African (SSA) countries have developed national policies, legislations, plans, and institutions that are geared towards biodiversity conservation and management. However, evidently lacking in these instruments is the mechanisms for the generation, processing and sharing of biodiversity information. This study reviews the current biodiversity policy and institutional landscapes, and their impacts on the generation, processing, sharing, and use of biodiversity information for decision-making in SSA. We employed an integrated approach for data collection including literature review, telephone interviews and questionnaire administration. Findings show that biodiversity information has primarily been mobilized in an *ad hoc* manner through project surveys and academic research endeavours. Currently, majority of SSA countries still do not have standalone biodiversity policies that could prioritize biodiversity information and provide specific mechanisms and structures for the mobilization, processing and sharing of biodiversity information. Rather, efforts have focused on mainstreaming strategies and action plans into related sector policies and planning activities with potential impacts on biodiversity information. This move has not been entirely successful in sustaining efforts on biodiversity data and information generation, utilization and sharing. While the relevance of biodiversity information for national development is acknowledged by stakeholders, there are still major obstacles including: the lack of funding for data mobilization, weak institutional capacity, lack of individual competencies, and inadequate training on techniques for mobilizing biodiversity data and information. Advocating for value-added and demand-driven biodiversity information has the potential to garner policy support and legitimacy to reach the level of importance required for investment, capacity development and specialised institutions for biodiversity conservation in SSA.

Key words: Biodiversity, information, policies, institutions, sub-Saharan Africa.

INTRODUCTION

Biodiversity provides a fundamental basis for economic livelihood and societal wellbeing in Africa (Cadman et al., 2010). It is vital for the health of the earth's ecosystem that survives the current and future generation. However, biodiversity worldwide is in danger with the predicted loss of species and genetic diversity as great as past mass extinction events (Jenkins, 2003; Loreau et al., 2006). The current rate of biodiversity loss is a major concern due to its negative implication for human survival on earth. The loss of each species comes with the loss of potential economic benefits as well as the reduction in efficiency and capacity of ecosystems to produce biomass, decompose, and recycle biologically essential nutrients (Attuquayefio and Fobil, 2005; Cardinale et al., 2012).

The growing concern for biodiversity loss and its adverse implications on humanity has attracted global attention leading to the proliferation of conventions, protocols and declarations which are aimed at encouraging countries to take serious actions to curb the imminent threat of biodiversity decline. It has also led to the establishment of global institutions, regional institutions and research institutions who are working together with donor agencies to highlight the gravity of biodiversity decline and to devise sustainable policy strategies and interventions to address the situation. However, the impact of these strategies and interventions on curtailing biodiversity loss remains elusive as the state of the world's biodiversity continues to change rapidly (Convention on Biological Diversity (CBD), 2010; Butchart et al., 2010).

Africa boasts of quite a sizeable proportion of the world's natural resources and biodiversity (African Development Bank (AfDB), 2015), yet this fundamental natural asset upon which survival depends is under severe threat. With increasing raw materials extraction for economic growth, land use changes, urbanization, and weak institutional arrangements, countries in Africa are experiencing unprecedented rate of resource exploitation in recent time. In addition, climate change phenomenon presents a new development threat to biodiversity and the future of majority of African rural population whose livelihoods are directly dependent on the biological resources.

Most African countries are signatories to several of international conventions, agreements and protocols regarding the conservation and protection of biological diversity. At the regional level, countries have also committed to initiatives and declaration in an attempt to safeguard biodiversity. As required by these commitments, countries are tasked to develop and implement national strategies, plans, or programmes for promoting the conservation and sustainable use of biological diversity. A major challenge for countries has been the translation of these international and regional regimes into practices at the local and national levels through well-defined policies, legal frameworks, and institutional structures (Kameri-Mbote and Cullet, 2002). Existing policies and institutional frameworks in African countries do not effectively incorporate biodiversity values into national development and planning agenda.

At a regional consultation dialogue, governments from African countries reported their inability to achieve the Africa biodiversity targets for 2010 citing the challenges of insufficient integration and prioritization of biodiversity into broader sector of the economy (UNEP, 2010). They also noted that greater attention on climate change issues at the national level had overshadowed biodiversity conservation efforts. Concerns were raised by governments on the failure of the scientific community to effectively articulate biodiversity issues to policymakers in ways that adequately make biodiversity a priority in the political and development agenda (UNEP, 2010). Following the disappointment of not achieving the 2010 biodiversity targets, governments launched an ambitious and elaborate Strategic Plan for Biodiversity 2011-2020, which targets the sustainability of resilient ecosystems and provision of essential services by halting biodiversity loss by 2020. In order to achieve this plan, the significant gap between science and policy required a serious attention. Policymakers must formulate the appropriate policies that would slow and end the rapid rate of biodiversity loss. Improving, sharing and applying biodiversity data and information (as set by the Aichi Target 19) will be essential for policy makers to monitor the status and patterns of biological resources and to model impact of changes.

While the availability and access to high quality information on biodiversity influences effective policy making for biodiversity and ecosystem services, the same is true when it comes to how effective policies can facilitate the generation and access to high quality data on biodiversity. Given the crucial role of biodiversity in the development of Africa's economy and the importance of high quality data to inform effective decision-making, it has become necessary to examine the current policies, legislations, and institutional landscapes necessary for capturing, digitalizing and processing of biodiversity data and information in SSA countries to enable them achieve biodiversity conservation targets. Specifically, the study set out to (i) analyse existing policy and institutional landscapes that influence the generation, maintenance and access to biodiversity information in SSA; (ii) assess the potential impacts of biodiversity information on biodiversity conservation and management; and (iii) assess the factors that affect biodiversity information management in SSA.

Theoretical underpinnings on biodiversity information

In an increasingly globalised and digitised era, the relevance of environmental information including biodiversity information to nature and society has never been more pronounced than before in the development of strategies and policies (Mol, 2006). There is a growing

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interest in exploring the role of digital technology in nature conservations as highlighted by van der Wal and Arts (2015) in the *Ambio Special Issue*. In this Issue, van der Wal and Arts (2015:1) introduced the idea of 'digital conservation', which capture 'developments at the interface of digital technology and nature conservation that influence conservation-related goals'. Such emerging area raises optimism among scientists and conservationists about the potential of digital conservation in providing high quality data and information, improved surveillance, and efficiency in managing biotic resources (van der Wal and Arts, 2015).

Information and associated networks and infrastructures are increasingly regarded as critical for understanding social issues as society enters the information age (Castells, 1997a, b). The capacity of information to create transformative environmental reforms does not principally rest on the substance of the information but rather on the ability to collect, process, transmit and use information, making information available and accessible to the mass of people and institutions, as well as globalising information flow (Mol, 2006). There is considerable evidence about the role of information in defining strategies, policies and decisions on sustainable development of biotic resources and ecosystem (Ariño et al., 2011). However, the impact and relevance of information on biodiversity and the progress made in driving policies and strategies have not been uniform globally. Biodiversity information in many SSA countries are limited, non-existent or scattered in varied format in national labs, museum, survey, and project reports. This situation hinders the exchange and the creation of a cohesive data and information on biodiversity. At a scientific workshop of a group of biodiversity informaticians in the region, participants highlighted a common challenge of aggregating and synthesising existing data and information on biological resources to form a structured, unified and meaningful biodiversity information system that can adequately inform strategies and actions for biodiversity conservation (Guralnick and Hill, 2009).

To harness the potential benefits of biodiversity information in an increasingly digitised economy, there is need to look at the policies, legislations and institutional arrangements, and examine how they can effectively embrace the values of biodiversity as integral part of development at the national and local levels. Biodiversity relevant policies hold the prospects of enhancing institutional and human capacity to promote the application and utilisation of biodiversity information for conservation decisions, biodiversity data exchange and sharing, regional cooperation, and biodiversity data capture in order to meet consumer needs.

Conceptual framework

Policies, legislations and institutions are complex with varied interpretations in literature. Several narratives have informed biodiversity policies and institutions for the management of biological resources across the globe. The following narratives have shaped development of national biodiversity policies, legislations and institutions: (i) the declining biological diversity and its threat on human existence, ecosystem and food security as result of continuous anthropogenic activities and the impact of environmental conditions; (ii) the rise of multiple international agreements, protocols and conventions which has influenced countries to commit themselves towards curbing biodiversity decline or loss; (iii) urgency with which actors must respond to reverse the loss of biological resources and to preserve biodiversity through policy strategies, legislations and institutions; and (iv) the critical aspect of generating biodiversity information that would effectively inform decision-making and national planning. The important question is to understand how policies, legislations and institutions function with a wide array of actors to influence the capture and processing of high quality data and information on biodiversity to inform actions and decision-making in sub-Saharan African countries. In understanding how these issues function, their impacts and implications, the paper articulates a conceptual model that guide the analysis of what and how biodiversity related policies, legislations and institutions shape biodiversity agenda as well as the generation, processing and access to vital information on biodiversity (Figure 1).

In this model, we identified two analytical lenses through which this study was carried out. The first is the policy analysis tool which would help to examine existing policies, legislations and institutions and their role in the conservation of biological resources as well as the generation, processing and use of biodiversity information for evidence-based decision-making. The second approach looks at the processes and contribution of biodiversity information to conservation and national development through the analytical lens of information economy (Castells, 1996).

Policy analysis

Under the policy analysis, various policies are examined to determine the ones with the potential to achieve a given set of goals considering the relations between the policies and the goals (Nagel 1999). Dunn (2015) defined policy analysis as "a process of multidisciplinary inquiry, designed to create, critically assess, and communicate information that is useful in understanding and improving policies". Policy analysis has become an essential tool for analysis of public policies aimed at reducing uncertainties, providing clear direction and systematic arrangements to improve public policymaking. As Walker (2000) pointed out, in the absence of analysis, important policy choices have been made based on hunches and guess work often resulting in undesirable outcomes. With

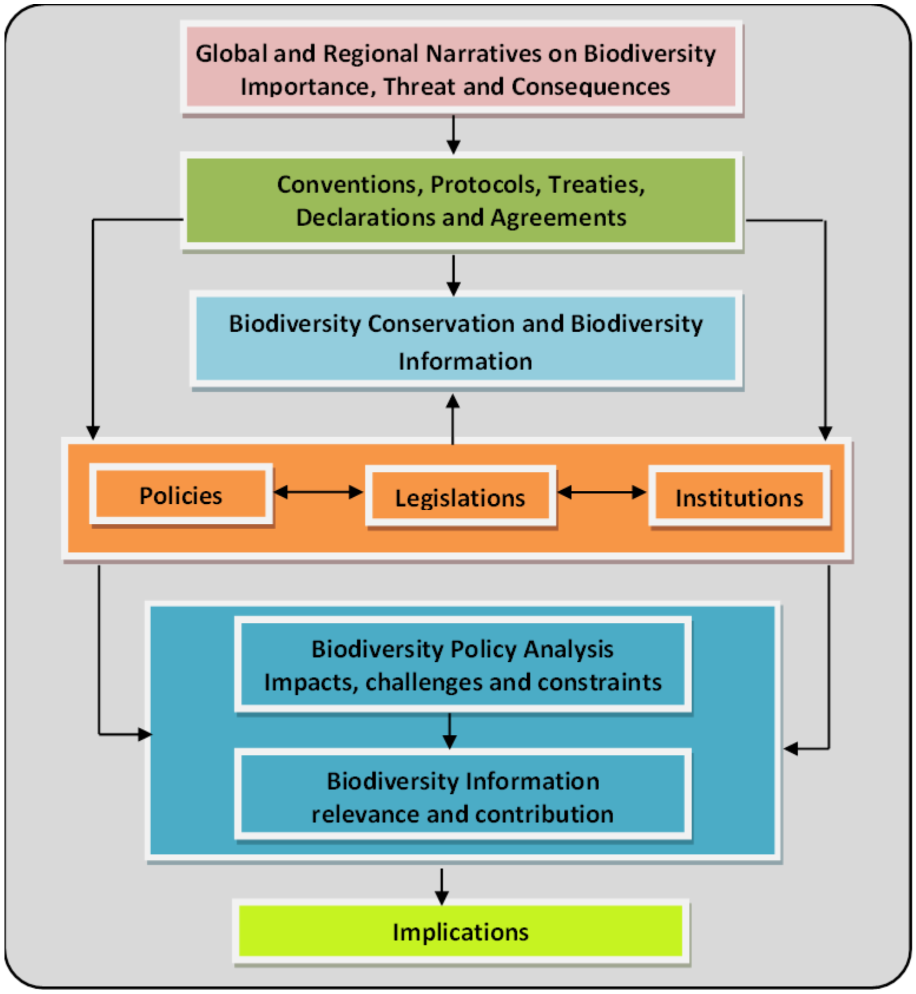

Figure 1. Conceptual model.

its root from systems analysis, policy analysis can be categorised into two main field of inquiry. The first entails analytical and descriptive analysis of existing policies with the aim to explain policies and their development. The second is prescriptive which deals with the analysis of new policy thus the formulation of policies and proposals (Bührs and Ton, 1993). The selection of policy analysis type is dependent on the area of interest and purpose of analysis. In this paper, we employ the former to analyse existing policies and institutions that are in one way or the other engaged in biodiversity conservation and management.

Several approaches to policy analysis have been identified. The four most commonly used approaches include: *Analysis 'of-for' policy, analycentric, policy process,* and *meta-policy approach.* The 'analysis 'of-for' policy' consists of two parts - analysis 'for' policy approach entails research that is commissioned by policy makers in order to actualise policy development, while the analysis 'of' policy approach is more of an academic research to understand the rational of the development of a particular policy at a particular time and their impacts (Khorsandi, 2014). The analycentric approach target individual problems at micro-level and aims to find effective and efficient solution in technical and economic terms (e.g. the most efficient allocation of resources). With a scope at meso-level and problem interpreted in a political way, the policy process approach place emphasis on the political process, involving stakeholders. The objective is to determine the processes and means used, clarifying the role and influence of stakeholders in the policy process. One way of achieving this objective is to use a heuristic policy cycle, which demonstrates an iterative policy-making process, and policy analysis involving logical performance steps (Weible et al., 2012). For the meta-policy approach, the scope is the macro-level and its problem interpretation is structural in nature. As a systems and context approach, the meta-policy approach brings out the contextual factors such as the economic, socio-cultural and political factors that influence the policy process. This study draws from the meta-policy approach to explain how policies and institutions emerged from global narratives on biodiversity decline and how these policies and institutions have shaped biodiversity conservations as well as the generation and use of information on biodiversity.

Information economy

According to Castells (1996, 1997), `information economy' highlights the role played by information in economic processes. It represents a specific form of economy in which the generation, processing and transmission of information becomes a vital source of power and productivity (Kember, 2003). The idea of an information economy is not only about the importance of information in economic processes but also about the fundamental transition of the economic imperative (Mol, 2006). The rise of a new technological paradigm, powered by information and communication technologies (ICTs), and connected to globalisation processes, is creating a transformation from which a fundamentally different social and economic order has emerged. Modern economies have become information-based because the prosperity of the economy in terms of productivity and competitiveness of units fundamentally rely on their ability to generate, process and use information (Castells, 1997). With the rising relevance of biodiversity information in socio-economic development processes, there is an opportunity to articulate pragmatic policies and realign institutions to prioritise the transmission, handling, processing, and sharing of biodiversity information for national development planning and conservation management.

MATERIALS AND METHODS

Study area

Geographically, sub-Saharan Africa lies south of the Sahara desert on the continent of Africa. It comprises about 49 sovereign countries widely spread in the southern, western, central and eastern part of Africa, with some eastern islands of Africa. According to the World Bank, the population was estimated to be 974 million as at 2014 (World Bank, 2014). Sub-Saharan Africa is characterized by very rich and diverse biological resources, which represent the region's natural wealth upon which socio-economic development is based. The SSA region is home to more than 900 amphibian species, 960 mammal species and approximately 1600 bird species (International Union for Conservation of Nature (IUCN) Red List, 2008).

Research methods and data analysis

The paper employed a mix of approaches for data collection and analyses. Both primary and secondary sources of data were utilized. This allowed for effective triangulation of data (Yeasmin and Rahman, 2012). The first part entailed content analyses of scientific literature, national policy documents, biodiversity strategy and action plans, global biodiversity databases, web content, conference documents and reports, national reports, and institutions that are responsible for biodiversity issues in SSA countries. This detailed literature review provided a useful overview of existing policies, institutional arrangements, frameworks and action plans for biodiversity conservation and management in sub-Saharan African countries. These outcomes informed the questions that were asked in the online survey.

The second part included the administration of an online survey using survey monkey. A semi-structured questionnaire was sent out to various experts and stakeholders to obtain information on current situation regarding biodiversity policies, the value of biodiversity information, relevance, challenges, and the impact of policies on the generation and access to biodiversity information and data. The semi-questionnaire included a set of open questions (questions that prompt discussion). The statements in the questionnaire were defined based on the initial literature assessment carried out on the subject. Two reasons inform this approach- one, to provide valuable information from the context of respondents' experiences, allowing them to explore responses further, and two, to provide uniformity (Horton et al., 2004). Respondents included representatives from government ministries and agencies responsible for biodiversity conservation, policymakers, and experts from research institutions, universities, non-governmental organizations, and biodiversity informaticians. A total of 60 respondents from 32 countries participated in the research through an online survey.

Primary data were collected at interval levels using a 5-point Likert-scale. The application of this ordinal scale allows users to measure the gradations in attitudes, opinions, and behaviors of respondents (Dillman et al., 2009). To determine the level of impact of biodiversity information on biodiversity management in SSA, participants were tasked to rate the predefined and open statements on a scale of 1 to 5 with the following rating: No impact = 1, low extent = 2, medium impact = 3, High impact = 4, Very high impact = 5. To assess the extent to which certain factors affect biodiversity information management and to assess the impact of biodiversity information on biodiversity management, we defined a 5- point rating scale which included: Very great extent = 5, Great extent = 4, Some extent = 3, Little extent = 2 and No extent = 1. Following the ratings by respondents, we calculated the mean scores and standard deviations of the various ratings by the respondents. We also set out a cut-off mark of 2.5 and below for all statements that were not significant.

RESULTS AND DISCUSSION

In the first part of this section, drawing from various documentations including literature, reports, plans and policies, we examined the policies and institutions that have emerged in response to the growing recognition of the importance of biodiversity and the alarming rate of biodiversity loss around the world. Based on the responses from the online survey conducted, the second part involves the analysis of the potential impact of existing policies, legislations and regulations on the processes that facilitate the generation of biodiversity information as well as the factors that affect the management of biodiversity information in sub-Saharan African countries.

Policy and institutional analysis on biodiversity in SSA

In recognizing the value of biodiversity to humanity and

Table 1. List of policies and legislations in SSA countries.

National policies and legislations	Countries
Biodiversity Policy	Nigeria, Rwanda, Ethiopia, South Africa
Forest Policy	Angola, Burundi, Kenya, Lesotho, Malawi, Mauritius, Namibia, Nigeria, Senegal, Somalia, Sudan, Togo, Zambia, Zimbabwe
Forest Code	Burkina Faso, Central African Republic, Ivory Coast, Guinea, Senegal
Forest Act	Botswana, Gambia, Kenya, Lesotho, Malawi, Mauritius, Sierra Leone, South Africa, Sudan, Uganda, Zambia, Zimbabwe
Forest Law	Benin, Burundi, Central African Republic, Ethiopia, Guinea Bissau, Liberia, Madagascar
Wildlife and Conservation Policy	Botswana, Ghana, Kenya, Mozambique
Forest and Wildlife Law	Cameroun,
Wildlife Policy	Eritrea, Namibia, South Sudan, Tanzania, Uganda, Zimbabwe
Wildlife Act	Gambia, Swaziland, Uganda, Zambia, Zimbabwe,
Wildlife Law	Ethiopia, Senegal
Wildlife Code	Ivory Coast, Guinea
Wildlife Conservation and National Park Act	Botswana, Benin, Ivory Coast, Guinea Bissau, Kenya, Lesotho, Liberia, Malawi, Sierra Leone, Sudan, Tanzania,
Environmental Policy	Ethiopia, Ghana, Lesotho, Liberia, Malawi, Mali, Mauritius, Mozambique, Nigeria, Rwanda, Somalia, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe
Environmental Management Act	Gambia, Ghana, Kenya, Lesotho, Malawi, Seychelles, Somalia, South Africa, Sudan, Swaziland, Uganda, Zambia,
Environmental Law	Angola, Comoros, Chad, Guinea Bissau, Liberia, Madagascar, Mali
Environmental Code	Burkina Faso, Guinea Bissau
Environmental Impact Assessment Act	Guinea Bissau, Mozambique, Seychelles, Uganda, Zambia, Zimbabwe
Fisheries Act	Gambia, Liberia, Rwanda, Tanzania,
Fisheries Policy	Kenya
Wetland Policy	Mali, Rwanda, Uganda, Zambia

survival of planet earth, the global community has over the past four decades established policies, institutional mechanisms and legislative instruments aimed at curbing the declining biodiversity, promoting sustainable use, and ensuring fair and equitable access to biological resources (Cardinale et al., 2012). At the 1992 Earth Summit in Rio, a global consensus was agreed upon by nations present about the impact of human actions in the destruction of biological diversity, ecosystems, and the elimination of genes and biological traits around the world at a disturbing rate. A major milestone was achieved when the Convention on Biological Diversity (CBD) was agreed and passed by member countries to promote the conservation, sustainable utilization, and fair and equitable benefit-sharing of biological resources. The CBD was regarded as the first global comprehensive multilateral agreement that placed environmental, social and economic goals on the same level. The CBD boasts of all the 198 countries who are signatories to the convention including all the sub-Saharan African countries.

Analysis of the various policies and documentary evidence in sub-Saharan African countries revealed that existing policies and legislative instruments on biodiversity have mainly focused on the sector-based issues such as environment, forest and wildlife resources (Table 1). For example, many SSA countries have created separate policies and legislative instruments such as forest policy, wildlife policy, environmental policy, forest code, wildlife act, fisheries act, environment management act, among others, which are implemented by different institutions with sometimes overlapping and duplications in responsibility.

Under the Convention on Biological Diversity, contracting parties were required to develop and implement national strategies, policies and action plans to address environmental and conservation issues. The convention in many ways contributed to the formulation of policies and institutions in sub-Saharan countries that are geared towards streamlining biodiversity issues into national development planning (Perrings and Lovett, 2000).

As a commitment to meet the requirement of the Article 6 of the CBD, all SSA countries have already put in place a National Biodiversity Strategy and Action Plan (NBSAP). The NBSAPs function as the policy strategy and implementation framework for biodiversity conservation, and in part viewed by most countries as a substitute for a standalone biodiversity policy. In spite of the effort made in policy and legal frameworks, there exists many gaps in relation to actual implementation of NBSAPs and biodiversity related policies in most SSA countries (Hens and Nath, 2003; Hens, 2006). Administrative level mandates for the implementation of NBSAP remain unclear. The review of NBSAP implementation in SSA countries highlighted the following challenges: the lack of coordination in implementing actions and compliance monitoring, limited understanding of the plan, and weak implementing institutions, among other factors. The implementation challenge raises question as to the suitability of the NBSAPs as policy strategy and action plan to guide the sustainable management of biodiversity conservation as well as the generation of biodiversity information to inform policy decision-making.

With the exception of Ethiopia, Nigeria, Rwanda and South Africa, most SSA countries do not have standalone biodiversity policy. In Nigeria, the National Policy on Conservation of Biological Diversity established in 1999 seeks to integrate biological diversity issues into national planning, and decision-making, and to conserve and enhance the sustainable use of biological diversity. The Biodiversity Policy for Rwanda was adopted and approved by parliament in 2011 and a law on biodiversity was passed in 2013. In this policy, the Government of Rwanda highlighted the scattered nature of biodiversity data and information in different sectors, and the need to ensure the mobilization, accessibility and management of data and information to support conservation and decision-making. South Africa's Biodiversity Policy and legislation instruments for biodiversity are well developed, providing a strong basis for the sustainable utilization and conservation of biological diversity. The White paper on Conservation and Sustainable use of South Africa's Biological Diversity (1997) laid the foundation for the establishment of a legislative framework for biodiversity. The Biodiversity Act (Act 10 of 2004) under the umbrella of the National Environment Management Act (1998) seeks to resolve the fragmented nature of biodiversity-related legislation by consolidating different laws and bring into effect the principle of cooperative governance. South Africa is among the very few countries with an established National Biodiversity Institute. Analyses of these countries' standalone biodiversity policies revealed the extent to which biodiversity issues are considered important within the national agenda.

Towards biodiversity information generation and access- the role of institutions in SSA countries

Several institutions and agencies at the national levels have notably been responsible for biodiversity issues in SSA countries. For instance, research institutions have been mainly responsible for the generation, collection and analysis of biodiversity data and information.

National Histories and Museums, and Herbaria play an essential role in biodiversity data and information storage and reference labs. The Forestry and Wildlife Services are responsible for the management of forest concessions, forest reserves, wildlife sanctuaries and national park systems. Non-Governmental Organizations have also played a role in biodiversity conservation, data generation, policy advocacy, and capacity building. Communities have emerged as legitimate local institutions responsible for creating and managing community forest and wildlife reserves. Such arrangement sometimes created a challenge for biodiversity management due to the lack of horizontal cooperation, ineffective collaboration and lack of information flow among the different institutions and agencies.

In the analyses of institutions in SSA countries, it became evident that many countries are yet to establish specialized institutions that facilitate the generation, processing and sharing of biodiversity data and information in Africa. Some renowned biodiversity institutions promoting the generation and storage of biological diversity data on Africa are domiciled outside Africa. For example, the African Biodiversity Information Centre (ABIC) based in Belgium provides African countries with information resources on biodiversity in the Royal Museum for Central Africa's (RMCA) animal and plant collections. Funded by Belgian Development Cooperation, the ABIC is an RMCA initiative which, as stipulated in the Convention on Biological Diversity signed by Belgium, aims to share data on African biodiversity with African institutions.

Recently, we are witnessing the emergence of several initiatives at the sub-regional and national levels that targets the generation, processing and use of biodiversity information. For instance, the East African Biodiversity Informatics project (EABIP), established in 2007 aims to develop a baseline for biodiversity data for monitoring, assessing and setting priorities for the conservation and sustainable use and development of biodiversity information in Kenya, Tanzania and Uganda. The initiative has established a working platform with existing regional initiatives, such as the Botanical and Zoological Network for Eastern Africa (BOZONET) and the East African Regional Initiative on Medicinal Plants (EARIMP) to coordinate information on taxonomy, biodiversity status and sustainable use. Another existing initiative is the ARCOS Biodiversity Information System (ARBMIS), a platform to promote data sharing and information exchange on biodiversity to support informed decision in the Albertine Rift region. Established in 2007, ARBMIS makes accessible data mobilized and published through the ARCOS standard Integrated Publishing Toolkit (IPT). At the country level, one noticeable initiative is the Tanzania Biodiversity Informatics Facility (TanBIF) which is an extensive, decentralized system of national biodiversity information units that aim to provide free and

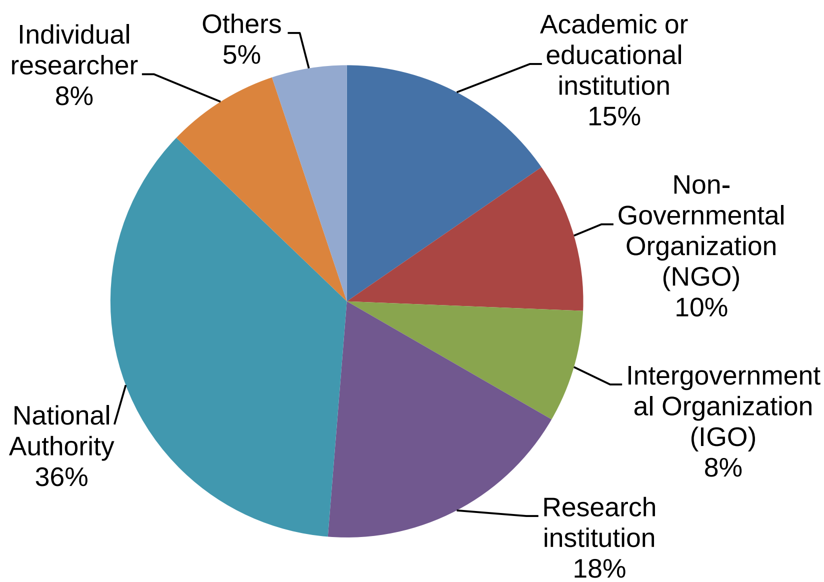

Figure 2. Background of survey respondents.

universal access to data and information on Tanzania's biodiversity. Established in 2008, TanBIF facilitates, mobilizes and digitizes primary biodiversity data; promote the use of scientific data in biodiversity policy and decision-making; and make biodiversity data and information universally available and accessible via the Internet.

Impact of biodiversity information on conservation and management in SSA

A total of 60 responses from the online survey were received from respondents in 32 out of the 49 sub-Saharan African countries. Respondents were from different institutions and different professional backgrounds that are all related to issues of biodiversity. The distribution of biodiversity experts and stakeholders that participated in the surveys is presented in Figure 2. Majority of the respondents (36%) were officials from government institutions, 18% were from research institutions, 15% worked with academic and educational institutions, 10% were from non-governmental organizations, and 8% each were from individual researchers and intergovernmental organizations. Only 5% came from other sources.

The fair distribution of the respondents across various stakeholder categories in the biodiversity sub-sector meant that information and data received were inclusive and capable of providing veritable guidance and policy direction on biodiversity information in the region. More so, the representation from up to 32 SSA countries provides room for diverse opinion which can be harmonized and used for generalization for both interventions and programmes.

Table 2 shows the mean scores and standard deviations from respondents on the impact of biodiversity information on biodiversity conservation and management in SSA. To determine the impact, respondents rated predefined impact statements on a scale of 1 to 5, with 1 being "no impact" and 5 being "Very high impact". The results showed that the mean scores of the ratings of the impact statements ranged between 3.9 and 4.40, According to respondents, all the impact statements defined in the table showed varying degrees of significance with their impact on the conservation and management of biodiversity. However, the most significant among the impact statements were on 'access and use of high quality biodiversity information (4.36); improved knowledge and understanding of biodiversity information (4.36); impact on environmental and ecosystem restoration (4.27 Integrated biodiversity information system (4.18); enhanced value of biodiversity conservation (4.18); and impact on plant and wildlife conservation (4.00). Several findings from other studies support the results from this study and emphasized the importance of biodiversity information and data in the management of biodiversity and prevention of environmental degradation (Bisby, 2000; Oliver et al., 2000; Edward et al., 2000; Krishtalka et al., 2002). The efficient mobilization of biodiversity information in a structured and unified form presents a new opportunity to understand the trend of biodiversity loss, while providing a vast amount of high quality and reliable information for sound policymaking (Peterson, 2003). It also offers a great potential to apply novel tools in numerous biodiversity studies ranging from prediction of species distribution and invasion (Raxworthy et al., 2003; Peterson, 2003),

Table 2. Mean scores of respondents on the impacts of biodiversity information on biodiversity conservation and management in SSA.

S/N	Statements	Mean	SD
1	Access and use of high quality biodiversity information	4.36	1.43
2	Integrated biodiversity information system	4.18	1.56
3	Facilitate national development agenda and decision-making	3.95	1.53
4	Improve academic and further research work	3.91	1.54
5	Impact of environmental and ecosystem restoration	4.27	1.31
6	Impact on plant and wildlife conservation	4.00	1.48
7	Impact on economic livelihoods	3.95	1.52
8	Improve knowledge and understanding of biodiversity information	4.36	1.43
9	Enhanced value of biodiversity conservation	4.18	1.44

*Cut-off mark- 2.5.

ecological and geographical distribution modeling (Canhos et al, 2004), and variability impact on biodiversity (Siqueira and Peterson, 2003; Thomas et al., 2004).

The Convention on Biological Diversity recognized that successful implementation of the convention heavily relies on the combined efforts of member countries and international organizations as well as integration of biodiversity knowledge and information systems (Canhos et al., 2004). Article 17 of the CBD demands "the exchange of information from all publicly available sources, relevant to the conservation and sustainable use of biological diversity" among contracting parties. "Such exchange of information shall include exchange of results of technical, scientific and socio-economic research, as well as information on training and surveying programmes, specialized knowledge, and indigenous and traditional knowledge" (Convention on Biological Diversity (CBD), 2010).

The cases of Ethiopia, Rwanda and South Africa provide visible impact of generation and use of biodiversity information to improve biodiversity conservation and management. For example, since 1998, the Ethiopian Biodiversity Institute has evolved to become the leading public institution responsible for undertaking research on Ethiopia's Biodiversity and associated indigenous knowledge; establishing participatory conservation mechanisms; ensuring fair and equitable access and benefit sharing; and promoting sustainable utilization of biodiversity for sustainable development. As an important strategy in the 2011 National Biodiversity Policy, the Rwandan Government plans to collaborate with stakeholders to establish a National Biodiversity Information Network (NBIN) and a National Biodiversity Information Management System (BIMS) to facilitate the collection, sharing, analysis, distribution and management of data and information for the biodiversity conservation and sustainable use. In South Africa, the South African Biodiversity Institute (SANBI) has built a reputation in biodiversity conservation beyond its national boundaries, becoming more of a regional institution that is SANBI in Partnership with Global Biodiversity Information Facility (GBIF) have organized a series of training and capacity building workshops to mobilize African biodiversity data while strengthening regional collaboration and capacity in biodiversity informatics. Availability of biodiversity information also had significant influence on the level of environmental degradation and plant and wildlife conservation. Countries with adequate information on the level of environmental degradation and biodiversity loss are more able to take informed steps to reduce degradation effects and minimize biodiversity loss (Peterson et al., 2002b; Siqueira and Peterson, 2003; Thomas et al., 2004).

Factors affecting biodiversity information management in sub-Saharan Africa

In Table 3, respondents ranked the factors affecting biodiversity information management in SSA which ranged between 3.80 and 4.20, with a cut-off mark of 2.5. Highly significant among the factors were the lack of funding (4.18) and the weak institutional capacity (4.05) for the generation, processing and management of biodiversity data and information. The results align with the findings of Muhumuza and Balkwill (2013) which reported that lack of adequate funding and improper government policy implementation are key factors affecting biodiversity information management in SSA. In majority of SSA countries, national financial priorities are far from being allocated to building biodiversity information systems and database. The largest proportion of investment in biodiversity conservation comes from foreign contributions. According to the Africa Environment Outlook 2, approximately US$ 245 million is invested annually by international donors for the management of protected area in SSA. The effectiveness of such investments in ensuring the conservation of biodiversity spearheading the field of biodiversity informatics in Africa. depends partly on the availability and reliability of

Table 3. Mean response on factors that affect biodiversity information management in SSA.

S/N	Statements	Mean	SD
1	Lack of funding	4.18	1.14
2	Weak institutional capacity	4.05	0.84
3	Lack of human capacity	3.95	0.95
4	Lack of equipment such as computers, models, application and tools	3.91	1.11
5	Lack of policy or poor policy implementation	3.82	1.06

*Cut-off mark- 2.5.

information on the spatial distribution and condition of biodiversity (Balmford and Gaston, 1999).

The lack of adequate funding to afford equipment coupled with the weak institutional capacity in terms of number of staff and expertise are major impediments to the generation, processing and digitization of biodiversity information in SSA countries. These challenges enumerated by respondents reflected the biodiversity information management experiences shared by participants at a recent project workshop of African biodiversity informaticians in Pretoria (SANBI, 2014). Majority of African professionals and their institutions (competency and capability respectively) are inadequately equipped with modern technologies and tools to generate and process biodiversity information. Employing new technologies and scientific approaches in the field of biodiversity has significantly improved the analysis, interpretation, integration, and visualization of biodiversity data and information (Canhos et al., 2004). While advances in hardware and software technologies for biodiversity information processing is improving globally, availability of these technologies and tools to the larger part of the world particularly the developing world is lagging behind (Swetnam and Reyers, 2011). Additionally, while growing biodiversity research is generating unprecedented quantity of data around the world (Scholes et al., 2008); significant volumes of such data continue to disappear after project completion (Güntsch and Berendsohn, 2008). In cases where data is available, there is high tendency for individuals, institutions and organizations to be reluctant to share data and information on biodiversity, which is driven by the notion that data users may profit “unfairly” or misinterpret the data. The availability and access to accurate and up-to-date information on biodiversity is considered as one of the main prerequisites for the successful implementation of biodiversity conservation and management programs (Swetnam and Reyers, 2011). There is a need to shift towards valued, demand-driven approaches towards the generation and processing of biodiversity information to transform behaviours while developing the competencies and capacities of individuals and institutions respectively on the application of emerging technologies and the values of biodiversity information management for national development.

Conclusion

In this paper, we have explored how the importance of biodiversity has risen over the past three decades due to the global recognition of rapid rate of biodiversity loss and its implication for sustainable socio-economic development. This global narrative triggered a global dialogue on biodiversity that have resulted in the establishment of conventions aimed at encouraging countries around the world to pay attention and commit towards addressing the imminent threat that is associated with the decline of biodiversity. In the light of this, we have witnessed the development of policies, legal instruments and networks of institutions that have sought to provide effective strategies and interventions to manage biological diversity sustainably. Yet, the implementation of these policies, strategies, and interventions to curb biodiversity loss has remained unsuccessful as the state of the world’s biodiversity continues to decline rapidly. In this paper, we have examined the policy and institutional landscapes in relationship with biodiversity issues including the generation, processing and use of biodiversity information to inform decision-making in sub-Saharan Africa countries. We have also looked at the impact of biodiversity information on biodiversity conservation and management and the factors that affect biodiversity information management.

Analysis of the various policies and documentary evidence in sub-Saharan African countries revealed that there are numerous policies and legislative instruments related to biodiversity that are mainly focused on sector-based issues such as forest, wildlife, fishery resources, among others. Many SSA countries formulated separate policies and legislative instruments such as forest policy, wildlife policy, environmental policy, forest code, wildlife act, fisheries act, and environment management act, among others that are implemented by different institutions with sometimes overlapping and duplications in responsibility. A major policy gap for biodiversity is that while all these policies are presumably geared toward biodiversity conservation and management, they have not been able to adequately address biodiversity due to the fact that biodiversity issues are spread between different policies and managed by different institutions.

Most of the SSA countries as revealed through the analysis do not have a standalone biodiversity policy that specifically target biodiversity issues including biodiversity information. In the analyses of institutions in SSA countries, it became evident that many countries are yet to establish specialized institutions that facilitate the generation, processing and access to biodiversity data and information in Africa.

The current status of information on biodiversity in sub-Saharan Africa (SSA) remains patchy and precarious due to multiple factors including lack of funding and investment in modern technologies for data generation, limited capacity of individuals and institutions to generate high quality biodiversity information, and lack of policies that target the generation, processing and use of biodiversity information. The efficient mobilization of biodiversity information in a structured and integrated format presents a new opportunity to understand the trend of biodiversity loss, while providing a vast amount of high quality and reliable information for sound policymaking. There is a need to shift towards valued, demand-driven approach for the generation and processing of biodiversity information to transform behaviours while developing policies, competencies and capacities of individuals and institutions on the application of emerging technologies and the values of biodiversity information management for national development.

Conflict of Interests

The authors have not declared any conflict of interests.

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